ORIGIN OF THE TRIASSIC TROUGH OF CONNECTICUT

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The paper by Professor W. M. Davis on "The Triassic Formation of Connecticut"[1] has long been regarded as a masterpiece in geologic literature. So well was the work done that little has been added to the knowledge of the Newark formation in Connecticut since its publication. Professor Davis did not, however, reach a definite conclusion concerning the origin of the trough within which the Newark sediments collected. Two hypotheses have been most widely held to explain the origin of the depression. It is the purpose of this paper to state briefly the field facts which bear upon these hypotheses and to suggest a method of research which may aid in the solution of the problem.

The two hypotheses referred to are: (1) the depression was formed by a gradual bending downward of a canoe-shaped trough without faulting movements (Fig. 1), and (2) the depression was developed by faulting movements on each side of the depression sedimentation (Fig. 2). Both of these hypotheses were suggested by Professor Davis in his report.[2] The fundamental hypothesis may be modified by certain limiting conditions. Professor Davis was inclined to believe that the formation of the trough was not accompanied by faulting. He also held that the original area covered by the Newark deposit was not much greater than that over which the series outcrops today.[3] Professor Grabau, while agreeing with Professor Davis in part, believes that a vast geosynclinal wedge extended from the eastern folds of the Old Appalachian Mountains, and that the present areas "are mere erosion remnants

[1] *Eighteenth Annual Report, U.S. Geol. Surv.* (1897), Part II, pp. 1–192.

[2] *Ibid.*, pp. 37–38. [3] *Ibid.*, p. 191.

of once much more extensive deposits . . . . preserved by being faulted beneath the level of erosion."[1]

Again, Professor Davis suggests that the trough may have been developed by faulting movements on each side of the depression (Fig. 2), whereas Professor Barrell[2] has limited the faulting to the eastern border (Fig. 3).

It is believed that there is general agreement with Professor Davis' statement that the "ancient mountains of Western Upland must

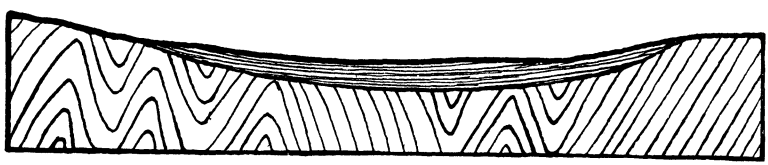


FIG. 1.—Diagram representing a depression formed by a gradual bending downward of a canoe-shaped trough, without faulting.

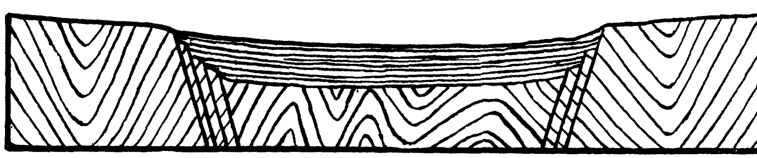


FIG. 2.—Diagram representing a depression developed by faulting which was continuous during the period of sedimentation.

have been worn down to a peneplain, or at least reduced to hills of moderate elevation and gentle slope, at the time the accumulation of the sandstones began."[3] It is further agreed that "the basement on which the Triassic strata rest" was worn "so low that no great additional amount of waste could be worn from it" had there not been depression of a central area accompanied by "correlated elevation of the adjoining areas on the west and east."[4]

Professor Davis goes on to say that "two suppositions may be made as to the character of these correlated elevations. The

[1] A. W. Grabau, *Text Book of Geology*, Vol. II, pp. 612–13.

[2] Joseph Barrell, "Central Connecticut in the Geologic Past," *Bulletin No. 23, Conn. State Geol. and Nat. Hist. Survey.*

[3] *Eighteenth Annual Report, U.S. Geol. Surv.*, Vol. II, p. 25.

[4] *Ibid.*, pp. 37–38.

trough may have been bent down between two arched areas on either side, as in Figure 1, or the trough may have been faulted down between two uplifted blocks alongside of it, as in Figure 2. While it did not seem advisable to make a final choice between the alternatives, the conditions illustrated by Figure 1 were favored, chiefly because the centripetal dips there shown would give, after general eastward tilting with more or less faulting, moderate dips for the lower strata in the east and stronger dips for the same strata in the

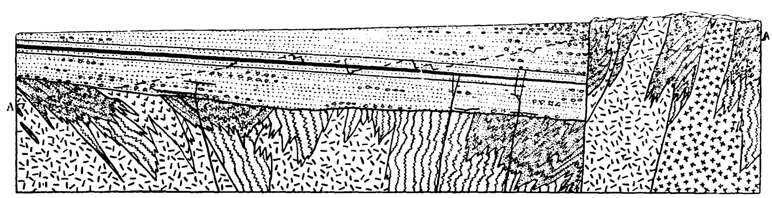


FIG. 3.—(After Barrell)

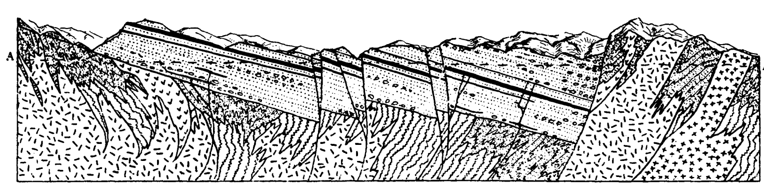
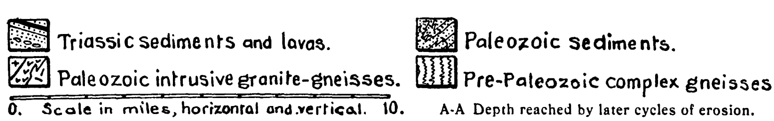


FIG. 4.—(After Barrell)



west. Professor Davis states that the field evidence showed an average dip to the east for the basal beds of 20° to 30° along the western border, and seldom more than 20° to the east for the analogous beds where exposed along the eastern.[1] His section, so widely copied in textbooks (Fig. 5), is therefore based on Fig. 1.

Professor Barrell, in his well-known study of "Central Connecticut in the Geologic Past," gives his conception of the origin of the depression. His idea is illustrated by Figures 3 and 4. A marginal fault of gradual development along the east side of the Connecticut

[1] *Eighteenth Annual Report, U.S. Geol. Surv.*, Vol. II, p. 39.

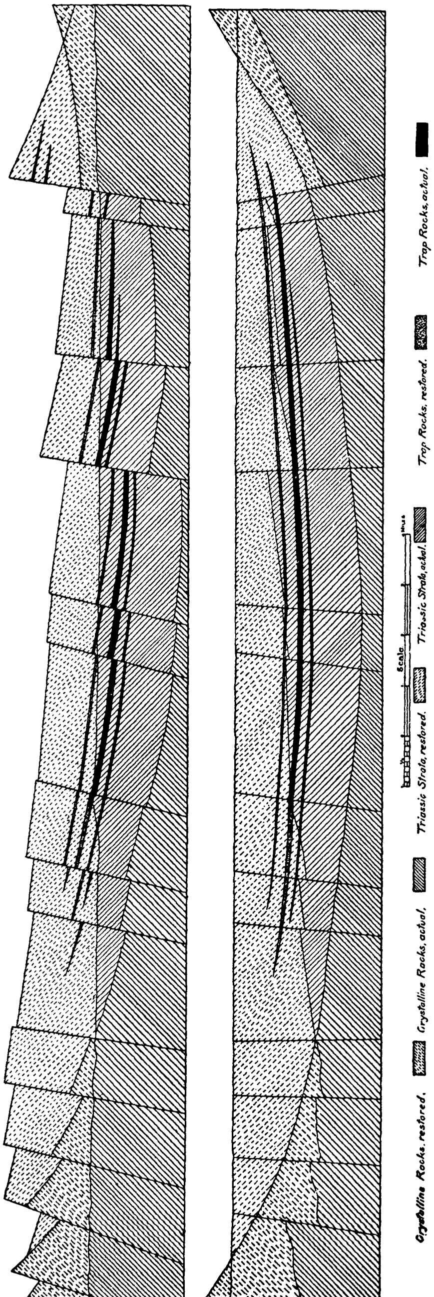


FIG. 5.—Sections across the Connecticut Valley Triassic. The upper section shows the present attitude of the formation as tilted and faulted. The parts which have been removed by erosion are restored. The lower section shows the supposed attitude of the formation before the tilting and faulting. (The shading with parallel lines does not represent planes of stratification.) From *Bulletin No. 6, Connecticut State Geological and Natural History Survey*, after Davis' figure in *Eighteenth Annual Report of U.S. Geological Survey.*

depression tilted the accumulating sediments toward the east and quickened the streams. Later smaller faults broke the trap flows and initiated the present topography (Fig. 4).[1] Professor Barrell supported his conception by the one statement that "the dominant segregation of conglomerates near the eastern margin is even more marked in the beds above the lava flows than in those below, and this greater average coarseness of the upper sediments indicates the intermittent regrowth of the mountains whose perennial waste kept supplying material for the basin."[2]

For reasons which will now be briefly stated the writer believes that Barrell's diagram represents most accurately the structure of the Connecticut depression during the Triassic.

1. A warping movement that distorts a peneplain surface without faulting must proceed very slowly. It is difficult to imagine that such a movement would revive the streams flowing into the Connecticut basin and cause them to transport bowlders of such a size as may be found not only in the edge but also toward the center of the trough. Cobbles 6 or 8 inches in diameter are found near the center of the valley, north of Meriden.[3]

2. Arkoses are common along the western border of the basin but are almost lacking along the eastern border, whereas coarse conglomerates are common along the eastern border but are seldom found along the western border. The inference is that the streams from the west were carrying the exfoliation products of a desert topography, but those from the east were carrying bowlders snatched from the wall of a growing fault scarp.

3. A consideration of the geometry of the geosynclinal hypothesis of Davis and the fault-monoclinal hypothesis of Barrell leads to conclusions which are more favorable to the latter. In Figures 6 and 7, let W represent the width of the Connecticut Valley. In northern Connecticut this width is approximately 21 miles; at Middletown it is 17 miles, or, if the Pomperaug Valley area is included within the larger basin, the width becomes 33 miles. Let D represent the depth of sedimentation within the basin. Compe-

[1] *Bulletin No. 23, Conn. State Geol. and Nat. Hist. Survey*, p. 28.

[2] *Ibid.*, p 29.

[3] *Eighteenth Annual Report, U.S. Geol. Surv.*, Part II, p. 33.

tent opinion places this thickness between 12,000 and 13,000 feet or between $2\frac{1}{4}$ and $2\frac{1}{2}$ miles. Let a represent the angle of dip developed in the basal beds by the gradual depression of the trough. At the sides of the geosnycline the actual angle would be greater than that indicated whereas, at the center, the beds would be flat, since the basin would be concave (Fig. 5). In either Case I (Fig. 6) or Case II (Fig. 7) it should be noted that the beds laid down at

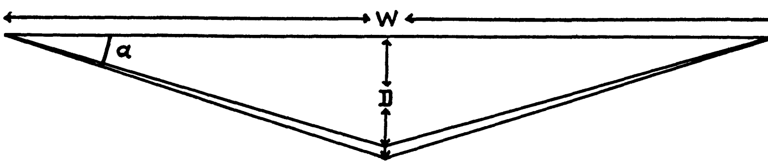


FIG. 6.—

Width	Depth	a
17	$2\frac{1}{4}$	$14\frac{1}{2}$
17	$2\frac{1}{2}$	$16\frac{1}{2}$
21	$2\frac{1}{4}$	12
21	$2\frac{1}{2}$	$13\frac{1}{4}$
33	$2\frac{1}{4}$	$7\frac{3}{4}$
33	$2\frac{1}{2}$	$8\frac{3}{4}$

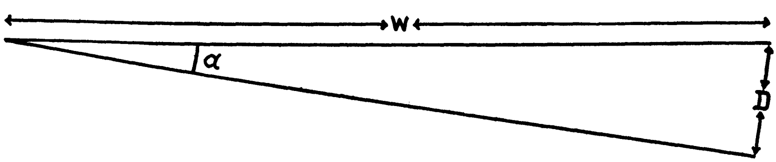


FIG. 7.—

Width	Depth	a
17	$2\frac{1}{4}$	$7\frac{1}{2}$
17	$2\frac{1}{2}$	$8\frac{1}{4}$
21	$2\frac{1}{4}$	$6\frac{1}{4}$
21	$2\frac{1}{2}$	7

the close of the period of sedimentation were approxiamtely horizontal, a fact overlooked by some writers. The diagrams are drawn to scale for a width of 17 miles and depths of $2\frac{1}{4}$ and $2\frac{1}{2}$ miles, respectively.

Whether the geosynclinal or the fault-monoclinal hypothesis be accepted, the present dips of the sediments of the basin were produced at the time of the post-Triassic faulting movements which tilted the rocks to the east. It would be advantageous to compare

the dips of the beds at the same horizon on the two sides of the trough, but only basal beds are exposed on the western side of the valley and upper beds on the eastern side. It is, however, possible to compare the known dips of the upper beds to the east with the dips of the basal beds to the west. Allowing for an erosion of 500 feet, the beds at the eastern side of the valley cannot lie far below the top of the series. Their original attitude at the close of the Triassic sedimentation was approximately horizontal. In the case of the geosynclinal hypothesis there may have been a slight dip to the west; in the case of the fault-monoclinal hypothesis, possibly a slight dip to the east. At present they have an average dip of 15° to 20° to the east. It is difficult to believe that the post-Triassic tilting was very dissimilar on the two sides of the valley. If it is assumed that the present dip of the upper beds was developed entirely at the time of the post-Triassic faulting, and that the tilt was, therefore, approximately 20° to the east, then, by adding 20° to the angle α, the present angle of dip of the basal beds at the western side of the valley should be obtained. Davis (see above) states that the average dip of the basal beds on the western side of the valley is 20° to 30°. In Case I (Fig. 6) by the foregoing method, the dips should be from 30° to 40°. In Case II (Fig. 7), angles from 20° to 30° are to be expected. It is true that, if the Pomperaug Valley area is included within the main basin, the results are inconclusive, but few authorities believe the original basin was much larger than it is today.

Assuming that the present dip of the upper beds of the Newark series at the eastern side of the valley represents the approximate angle of tilt to the east developed at the time of the post-Triassic faulting, then referring to Davis' diagram (Fig. 5), and conceiving that the present width of the valley was its approximate width in the Triassic period, in Case I the present dips should vary only slightly from the east toward the center of the valley, averaging perhaps a little lower about midway between the two points, but they should rise to a maximum at the western border. No normal dips near the center should be greater than the dips at the eastern border. In Case II there should be a progressive increase in dip

from the eastern to the western side of the valley.[1] The data concerning the strikes and dips within the Connecticut trough have never been assembled. Professor Davis' general statement quoted above would lead one to suppose, however, that there is an increase in the dips from the eastern toward the western side of the depression.

4. Pebbles in the upper conglomerates at the eastern border of the basin are known to be similar to rocks exposed at the very edge of the eastern upland. This condition is especially true near Lake Quonnipaug in Durham, Connecticut. East of the lake a chlorite schist, which is not common within the metamorphic rocks of the upland, outcrops for a mile or two. West of the lake the coarse "fan-glomerates" are filled with pebbles of this rock. The evidence indicates that the eastern limit of the Newark formation is at its ancient boundary, as Barrell's hypothesis would postulate, and that the basin sediments never extended over the eastern upland. If the eastern and marginal fault developed after the period of sedimentation, the chlorite schist at Lake Quonnipaug could not have been exposed to erosion at the time the "fan-glomerates" were being deposited.

5. The abundant development of those rocks so aptly named "fan-glomerates" by the western geologists along the eastern side of the basin is, in itself, strong evidence of the early initiation of faulting movements along this boundary. Such conglomerates are common throughout the exposed thickness of the Totoket block, but are not known on the western side of the valley.[2]

6. Finally, there is good evidence of the localization of vulcanism along the eastern fault line long before the end of the period of deposition within the basin. The writer has recently discovered a volcanic neck, in the southern part of Durham, north of Totoket Mountain, which lies within a stone's throw of the eastern fault margin.

[1] Excessive dips to the east are known near the eastern boundary fault. They are in the opposite direction from the drag dips which one would expect in this vicinity and have not been explained.

[2] Cf. C. R. Longwell, *Amer. Jour. Sci.*, IV (1922), 234–35.

For the reasons stated, the writer conceives of the Triassic basins of eastern Canada and the United States as a series of troughs of the basin range type which were developed during the collapse of the ancient land of Appalachia after the Appalachian mountain-building episode.

The Vale of Eden at the western base of the Pennine escarpment in northern England offers an interesting parallel to the inferred structure of the Connecticut Valley. Kendall has described the geology of the vale as follows:

> The succession in the Vale of Eden is of particular interest from the evidence that it furnishes of the physical conditions of the period and their changes. The valley is bounded on the east by the Pennine escarpment which owes its existence to a tremendous series of faults truncating the Permian and later rocks. The succession from west to east is: Carboniferous Limestone and Millstone Grit, covered unconformably by massive calcareous conglomerates, "Lower Brockram," usually dolomitized; bright red Penrith Sandstone about 300 m. (1,000 ft.); "Upper Brockram" interbedded in the upper part of the Penrith sandstone; Hilton Plant Beds with *Noeggerathia*, 45 m. (150 ft.); Magnesian Limestone 0–6 m. (0–20 ft.); Marls with gypsum having, locally, a basal conglomerate, 90 m. (300 ft.); St. Bees Sandstone (Trias) 600 m. (200 ft.)
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> The materials of the Lower and Upper Brockrams respectively furnish evidence of contemporaneous movement of the adjacent fault zone. The Lower Brockram consists exclusively of fragments of Carboniferous Limestone and the writer (Kendall) infers that it represents gravel-fans washed by torrential rains from the uplifted fault country, when the displacements had exposed only that division of the Carboniferous series. The Upper Brockrams were laid down after the deposition of 300 m. (1,000 ft.) of Penrith Sandstone, which should have covered up an equivalent portion of the faulted area, yet these Brockrams consist in large measure of the Basement Conglomerate of the Carboniferous series, with occasional pebbles of the underlying Ordovician rocks. This is interpreted to mean that between the formation of the two Brockrams a great further movement of the faults took place bringing the base of the Carboniferous up within the action of surface erosion.[1]

The eastern upland of Connecticut consists of such a tangle of metamorphic rocks that the rock succession is difficult to interpret.

[1] "The British Isles," *Handbuch der Regionalen Geologie*, Band III, Abteilung 1, p. 188. The writer is indebted to Professor Fearnsides, of Sheffield University, for calling his attention to the parallelism here described. "Brockram" is a local term used in the Vale of Eden for the rock known to the western geologists as a "fanglomerate."

However, the description of the geology of the Vale of Eden suggests a possible problem in sedimentation. A detailed study of the rocks of the eastern upland near the fault zone, combined with a microscopic study of the Anterior, Posterior, and Upper sandstones of the Connecticut Valley deposits might yield further evidence of the progressive growth of the eastern fault during the period of sedimentation.